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Effects of Different Soil-water-fertilizer Management Practices on Tagged Fertilizer N Uptake by Rice in Amazon Varzea and Sacramento Clay[1]

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Abstract : Using ^{15}N-tagged ammonium sulfate fertilizers as tracers, the uptake of fertilizer N by rice (*Oryza sativa* L.) as influenecd by different soil-water-fertilizer management practices in Amazon varzea soil and Sacramento clay were studied under pot culture conditions. Depending on the practices the recovery of fertilizer N by rice at flowering stage was 60 to 67% in the Amazon varzea soil, while this was 25 to 59% in the Sacramento clay. Those practices which may increase development of aerobic conditions or diffusion of the applied N to the oxidized soil layers greatly reduced the applied N uptake in the Sacramento clay. This was not the case in the Amazon varzea soil. The ammonium-N applied in the Sacramento clay was found to be quickly nitrified under aerobic conditions while this was not so in the Amazon varzea soil. The soil organisms in the two soils immoblized nearly the same amount of fertilizer N (19 to 21%) while only the former soil showed some fertilizer N fixation (2 to 5%) by clay minerals which appeared to contribute some reduction in the recovery of the fertilizer N by rice. It was concluded that marked difference in the tagged N uptake depending on various practices or conditions between the two soils is attributed mainly to the high nitrification and partly to the N fixation by the clay minerals in the Sacramentoclay. Therefore, the practices (deep placement, continous flooding, slowly releasing N fertilizers and nitrification inhibitors) which may minimize the fertilizer N loss through minimizing development of nitrification may not be particularly needed in the Amazon varzea soils having very low nitrification.

Introduction

In the lower Amazon basin of Northern Brazil, there are vast areas of marshland soils (locally called "varzea") and plenty of water resource which can be used for rice production (IRI Research Institute, 1970; IRI Research Institute, 1975; and McIntyre,

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1972). In 1969, a scheme was initiated to develop mechanized rice production in the Amazon basin (IRI Research Institute, 1970; and Wang et al. 1976). Through more than thirteen years research and development, a rice culture technology was developed to produce reasonably good yield (averaging 4.2 to 4.9 tons/ha/crop for 2 crops/year) in a large scale commercial production by continuous planting method (Wang, 1985). When the varzea soils are reclaimed for rice production, the soils in most area have a high level of organic matter (5—8%) and yield 5 to 8 tons/ha of grain with moderate amount (60—30—30 kg/ha) of NPK fertilizer. However, the N requirement increases with number of crops. After 3 to 4 crops, 90 to 120 kg/ha of N is required to produce 5—6 t/ha of grain commercially (IRI Research Institute, 1978; IRI Research Institute, 1981; and Wang, 1985).

Absorption efficiency of applied fertilizer N by rice (*Oryza Sativa* L.) is greatly affected by numerous environmental factors involving soils, climate and soil-water-fertilizer management practices (Broadbent and Mikkelsen, 1968; Cao et al., 1984 a; Cao et al., 1984 b; De Datta, 1981; Miears and Patrick, 1960; Mikkelsen and Finfrock, 1957; and Mitsui, 1956). Information of this on the Amazon varzea soils is extremely limited and needed for establishment of proper N fertilization techniques for rice production in the Amazon basin. In this investigation, using ^{15}N-enriched and ^{15}N-depleted ammonium sulfate fertilizers as tracers, the effects of different soil-water-fertilizer management practices on the uptake of fertilizer N by rice were determined in Amazon varzea soil and Sacramento clay under pot culture conditions. Different practices investigated involved two land preparation (dryland and puddled), several N placements (banded vs mixed and deep vs broadcast), different water managements during the stand establishment, and rate of N application. Sacramento clay, one of the principal rice soils in California (Mikkelsen and Evatt, 1973) and one for which the fate and behavior of N have been well studied, was selected as a standard with which to compare the Amazon soil. ^{15}N tracer techniques had been used previously on Sacramento clay and other California soils (Broadbent and Mikkelsen, 1968; and Manguiat and Broadbent, 1977), and proper N fertilization techniques developed for them (Mikkelsen and Finfrock, 1957; Mikkelsen and Miller, 1968; and Mikkelsen and Evatt, 1973).

Experimental Procedure

Soils--Amazon varzea soil and Sacramento clay were collected, respectively, from a newly reclaimed rice field at Jari Rice Project in the lower Amazon basin of Brazil and a rice field in California. The main properties of the two soils are shown in Table 1. More information on the Amazon varzea soils for rice culture at the Jari Rice Project is presented elsewhere (Wana et al., 1976).

Pot Culture Experiments

Four pot experimets were carried out to determine the effects of different soil-water-fertilizer management practices on the uptakes of fertilizer N and soil N. The first and second experiments were carried out at University of California-Davis while

Table 1. Properties of soils used[a]

Soils	pH	Org. C %	Tot. N %	C. E. C. c mol(+)/kg
Amazon varzea soil	5.1	2.70	.266	22
Sacramento clay.	6.8	1.78	.132	54

[a]. Taxonomic classification :
Sacramento clay: Vertic Haploaquolls Amazon varzea soil: Tropaquepts
pH. H_2O: soil=1 : 1
Org. C. Wet combustion method
Tot. N. Kjeldahl method
C. E. C. Ammonium acetate method.

the third and forth experiments were carried out at Jari Rice Project, Sao Raimundo, Belem, Para, the Amazon basin, Brazil.

Pot Culture Experiment #1.

Using Sacramento clay the effects of a number of different soil-water-fertilizer management practices on uptakes of the tagged soil fertilizer N and soil N were determined. Before the soils were potted, they were fully air dried and passed through a 5 mm sieve. Two kg lots of the soil were weighed into plastic pots lined with polyethylene bags. Except a few pots in which different rates of N were used, all pots received 400mg N as $(NH_4)_2SO_4$ of either ^{15}N-enriched (4.155 atom% ^{15}N) or ^{15}N-depleted (0.0072 atom % ^{15}N). This would give 200 mg/ka N on air dry soil basis. All pots received enough P and K with KH_2PO_4 (90 mg/kg P and 110 mg/kg K) and 20 mg each of iron and zinc (in chelate materials) at 14 days after seeding. For dryland preparation, N fertilizers were applied in 20 ml of solution by inserting a pipette to a depth of 5cm depth. This was to simulate a band application to achieve a deep placement.

For the puddled soil preparation, the N fertilizer solution was first added on the surface of the puddled soil and then incorporate into a depth of 5 cm by hand using a stainless steel spatula. This was to simulate incorporation of N fertilizer under puddled condition, which was considered to be the most likely method in which deep placement of the fertilizer into the soils could be achieved under the wet and puddled condition.

Different soil-water-fertilizer management practices examined were as follows :

(A). Eight factorial conmbinations of two land preparations (dryland and puddled) and four water managements for stand establishment.

Two land preparations

1). Dryland (Approximately 5 mm and less in particle size)

2). Puddled (Puddling was done mechanically by hand with a steel spatula to a depth of 5 cm depth)

Four water managements for stand establishment

1). Continuous flooding after seedling or zero day drainage (0 DD)

2). Three days drainage after seeding before reflooding (3 DD)

3). Seven days drainage after seeding before reflooding (7 DD)

4). Fourteen days drainage after seeding before reflooding (14 DD)

(B). Two placements (under dryland and 0 DD condition)

1). Broadcast on the surface of soil at 14 days after seeding.

2). Deep placement (banded at a 5 cm depth).

(C). Four rates of nitrogen application (under dryland and 0 DD condition)

1). 0 mg/kg N

2). 100 mg/kg N

3). 200 mg/kg N

4). 400 mg/kg N.

Each treatment was replicated four times in a randomized complete block desigh. The first and second blocks were applied with ^{15}N-enriched fertilizer and second and fourth blocks with ^{15}N-depleted fertilizer. Immediately after application of nitrogen fertilizer the pots were flooded with water to a depth of 5 cm. One day after the pots were flooded, 10 pregerminated rice seeds (*Oryza sativa* L. var. "Earlirose") were placed in each pot. For those treatments which required drainage (3 DD, 7 DD and 14 DD), water was drained by siphoning one day after seeding. Seven to 10 days after seeding each pot was thinned to 5 seedlings. Hand weeding was used to control the weeds. One day after flowering (66 days after seeding), the plants were cut off as near the soil surface as possible for the dry matter yield and N uptake (untagged and tagged N) determination. For several treatments, the root growth and N-uptake by roots were also determined to determine the balance sheet of tagged N in plant-soil system.

Pot Culture Experiments #2

In this pot experiment, the effects of land preparations (dryland and puddled) and two N placements (banded and mixed) were determined for the Amazon varzea soil and Sacramento clay. In pot experiment #1, it was not possible to distinguish the effect of the land preparation from that of placement, and this was made possible in pot culture #2. Due to a limited amount of Amazon varzea soil available, small pots (.25kg. of soil per each pot) were used. The same method as that used for the experiment #1 was to grow Earlirose rice. All pots received 200 mg/kg N (air dry soil basis) of ^{15}N-enriched ammonium sulfate fertilizer. The treatments involved :

1). Dryland preparation with the N fertilizer banded at a 3 cm depth (Dry-Banded)

2). Dryland preparation with the N fertilizer mixed thoroughly with soil up to a depth of 3 cm (Dry-Mixed)

3). Puddled with the N fertilizer banded at a 3 cm depth (Puddled-Banded)

4). Puddled with the N-fertilizer mixed thoroughly with soil up to a depth of 3 cm (Puddled-Mixed).

The treatment of 3)-Puddled-Mixed was not carried out for the Amazon varzea soil because the soil was not enough. Each treatment was replicated two times in a randomized complete block design. All pots were kept flooded continouously until heading. One day after heading (61 DAS), the top was cut for the yield and N uptake determination. Roots were also separated from the soils for determination of the balance sheet of the tagged N in the soil-plant system.

Pot Culture Experiment #3

This experiment was conducted at Jari Rice Project in Brazil to determine the effects of placements (deep placement and broadcast) and prolonged draining (14 DD) after seeding on the uptake of tagged N in the Amazon varzea soil. The soil was prepared under dryland condition. ^{15}N-enriched ammonium sulfate fertilizer was used as a tracer. The treatments investigated were :

1). N fertilizer banded at a 5 cm depth below the soil surface and kept flooded continuously (0 DD)
2). N fertilizer banded at a depth of 5 cm and kept for fourteen days drainage after seeding then reflooded (14 D D)
3). N fertilizer broadcasted on the soil surface at 14 days after seeding and kept flooded continuously (0 DD).

All pots (3 kg soils per each pot) received 200 mg/kg N on soil basis. IR 22 rice variety (*Oryza sativa* L.) was used as an indicator. Each treatment was replicated three times in a randomized complete block. The plants were cut one day after heading (80 DAS) for the dry matter yield and the N uptake determination.

Pot Culture Experiment #4

Using ^{15}N-depleted ammonium fertilizer as a tracer, the fertilizer N uptake efficiency as influenced by 4 rates of N application (0, 100, 200 and 300 mg/kg) was determined for the Amazon varzea soil at Jari Rice Rice Project, Brazil. The same method and rice variety (IR 22) used in pot experiment #3 were used. The plants at heading (B8 DAS) were cut for the dry matter yield and the N uptake determination.

Analytical Methods

The plant and soil samples were analyzed for total Kjeldhal N and the tagged N contents (Bremmer, 1965 a and Bremmer, 1965 b). A massspectrometer with a capacity of a precision of .001 atom $\%^{15}N$ was used to analyze the tagged N.

The transformation of ammonium sulfate in soils was determined as follows: Ten (10) mg N as ammonium sulfate dissolved in 1 ml solution was added to 50 gm of air-dried soils in an Erlenmeyer flask, and sufficient water was added to bring to the field capacity moisture content. This gave 200 mg/kg N on soil basis. The flask was stopped with a solid stopper with a small hole in the center of the stopper and incubated at the room temperature (25°C). At varying intervals ammonium was extracted with 150 ml solution containing 1 N NaCl-0.1 N HCl. The soil extract was made to 200 ml with water. Ammonium-N was determined by distillation with MgO. After the ammonium-N was distilled over, the receiver was changed, and Devardas alloy and additional water were added to the distillation flask. The nitrate plus nitrite was determined by a second distillation.

Clay-fixed ammonium in soils was analyzed by using the method of Dhaiwal and Stevenson (1958). Organic N in soils was determined by getting the difference between the values of total N and clay-fixed ammonium.

Rerults and Discussions

Effects of Different Soil-Water-Fertilizer Practices Tagged Fertilizer N Uptake.

Effects of different soil-water-fertilization practices on tagged N uptake are given in Table 2. The practices involved land preparations (dryland vs puddled), placements (banded vs mixed and deep placement vs broadcast), water managements during stand establishment (0 DD, 3 DD, 7 DD and 14 DD) and different rates of N application (100 to 400 mg/kg). It was interesting to find that the uptake of tagged N in the Sacramento clay was greatly affected by different land preparations, placements, and water magements, while this was not the case in the Amazon varzea soils.

In the Sacramento clay puddled reduced the N uptake and this was especially ob-

Table 2. Effect of various soil-water-fertilization management practices on tagged fertilizer N uptake in Amazon varzea soil and Sacramento clay

Treatment	Source of pot expt.	Tagged fertilizer N uptake			
		Amazon varzea soil		Sacramento clay	
		mg/kg	%	mg/kg	%
Land preparation					
Dry (N banded)	#1			205	51.3
Puddled (N mixed)	#1			121	30.3
$LSD_{.05}$				20	5
CV (%)				12.3	12.3
Dry	#2	125.6	62.8	64.4	32.2
Puddled	#2	126.4	63.2	53.4	26.7
$LSD_{.05}$		NS	NS	NS	NS
CV (%)		8.3	8.3	8.3	8.3
N placement					
Banded	#2	118.8	59.4	70.2	35.1
Mixed	#2	129.2	64.6	49.4	24.7
$LSD_{.05}$		NS	NS	10.4	5.2
CV (%)		8.3	8.3	8.3	8.3
Deep placement	#3& #1(1)	132	66	105	52.5
Broadcast	#3& #1(1)	128.3	64.2	87	43.5
$LSD_{.05}$		NS	NS	10.5	5.3
CV (%)		6.4	6.4	9.1	9.1
Water management					
0 DD	#3& #1(1)	132.0	66.0	112.5	56.3
3 DD	#1			106.0	53.0
7 DD	#1			105.0	52.5
14 DD	#3& #1(1)	137.3	68.7	86.5	38.3
$LSD_{.05}$		NS	NS	10.5	5.3
CV (%)		6.4	6.4	9.1	9.1
Fertilizer N rate			65.9		
100 mg/kg	#4& #1(2)	65.9	66.0	48.2	48.2
200 mg/kg	#4& #1(2)	132.0	66.5	106.2	53.1
300 mg/kg	#4	198.0			
400 mg/kg	#1			237.2	59.3
$LSD_{.05}$		34.5		16.4	
CV (%)		10.7		10.5	

(1) #3 and #1 for Amazon varzea soil and Sacramento clay, respectively.

(2) #4 and #1 for Amazon varzea soil and Sacramento clay, respectively.

vious when the N was mixed (incorporated) into the soil under puddled condition as compared with that under dryland-banded. When the N was banded at a depth of 5 cm under dryland condition the N uptake efficiency was 51.3%, and this was greatly reduced to 30.3% under the puddled-mixed condition. In pot experiment #2 in which the average N uptake efficiency through the two N application methods (mixed and banded) was found to be 27.6% under puddled condition, while this under dryland preparation was increased to 35.2% though not significant at 5%.

In pot experiment #2, the tagged N uptake efficiency in the Sacramento clay was 24.6% when the N was incorporated into the top layer of a 3 cm depth, while this was greatly increased to 35.2% when the N was banded at 3 cm below the soil surface. In experiment #1, the tagged N uptake efficiency was 43.5% when the N was broadcasted on the soil surface while this was increased to 52.5% when the N was banded at 5 cm below the soil surface.

In the Sacramento clay the tagged N uptake efficiency was greatly reduced (38.3%) when the soil in which N was banded at 5 cm below the soil surface was drained for 14 days during the stand establishment. When the soil was drained for a period not more 3 to 7 days, the N uptake efficiecy was slightly reduced to 53% from that (56.3%) found in the continuous floodiog (0 DD), however, the reduction was not significant statistically.

It was very interesting to note that all of the practices (puddled, mixed, broadcaste and 14 DD) which reduced the tagged N uptake efficiency in the Sacramento clay did not affect the N uptake efficiency in the Amazon varzea soil. On the contrary, most of them (puddled, mixed and 14 DD) even slightly increased the N uptake efficiendy though the increase was not significant statistrally.

It was also found that the N uptake efficiencies in the Amazon varzea soil was obviously and consistently higher (59 to 67%) than that in the Sacramento clay (25 to 59%) under all the conditions investigated. The amount of the N uptake increased linearly with the amount applied in both of the soils (Fig. 1). However, in the Sacramento clay the efficiency of uptake increased with the rate, and for this reason, the N uptake was found to be a negative value at 0 rate of N when it was determined by a linear regression equation.

The marked reduction in the N uptake found in the Sacramento clay but not in the Amazon varzea soil due to different practices (puddled, mixed, broadcast and prolonged drainage) seems to be due to the difference in the rate of nitrification found between the two soils. In Fig. 2 the transformation of ammonium-N in the two soils under aerobic condition is illustrated and indicates that virtually no nitrification of the added ammonium-N took place over 14 days incubation in the Amazon soil, while nearly all of the added ammonium-N was nitrified in the Sacramento clay in the same period. After flooding rice soils differentiate into two layers, the top oxidized layer (.5 to 1cm) and the reduced layer below (Mitsui, 1956 and Ponnamperma, 1972). Ammonium form of N fertilizers in the oxidized layer is stable and not oxidized. And the nitrate formed from the added ammonium-N in the oxidized layer may be lost subsequently through

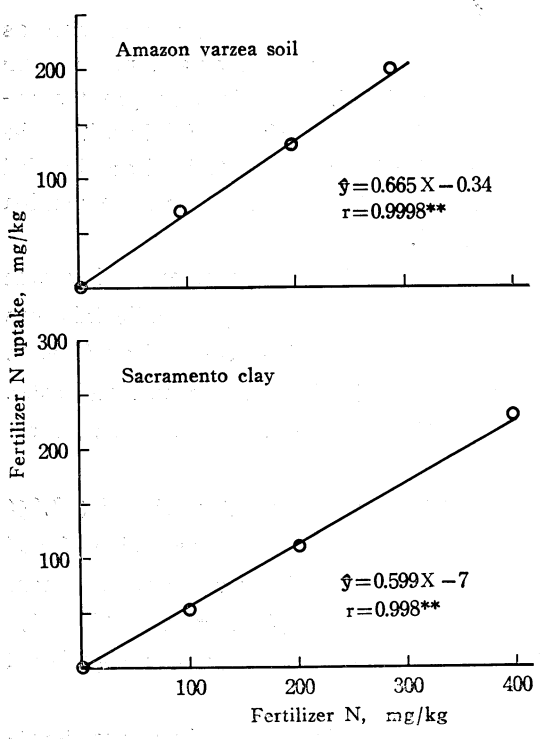

Fig. 1. Relation between fertilizer nitrogen uptake by rice and level of nitrgen applied in two soils.

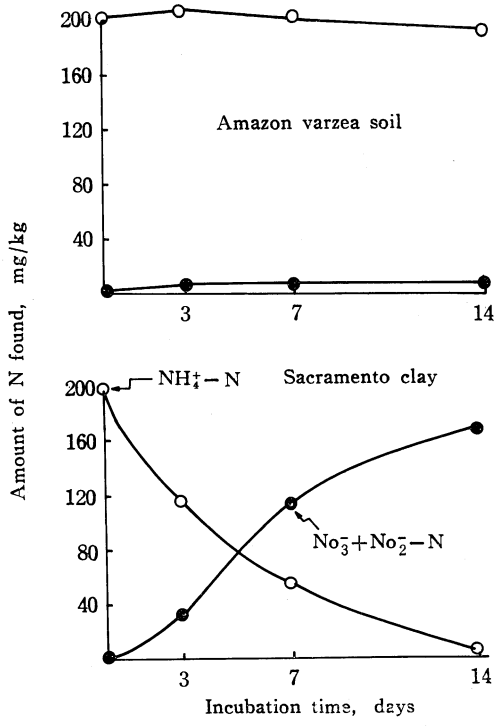

Fig. 2. Transformation over time of ammonium sulfate N (200mg-kg) in Amazon varzea soil and Sacramento clay under aerobic condition.

leaching or denitrification in the interlayers between the oxidized and reduced (Mitsui, 1956 and Ponnamperma, 1972).

When the ammonium-N was broadcasted on the surface of the Sacramento clay, the N was presumably nitrified quickly and then could be lost through denitrification. Since the nitrification rate in the Amazon varzea soil was very low, it is not unreasonably to expect that the broadcast did not reduce the N uptake in the Amazon varzea soil. In pot experiment #2 the N could diffuse to the oxidized layer more quickly wheh the N was mixed in the top 3 cm layer than when the N was banded at 3 cm below the soil surface. Therefore, the mixed application in the Sacramento clay substantially reduced the N uptake as compared with the banded application. However, the mixed application presumably reduce the N uptake in the Amazon varzea soil. On the contary, the mixed application apparently increased the interception of the N by the rice roots resulting in a small increase of the N uptake.

When the soils were drained after seeding, an aerobic condition might have developed in the soils depending on the length of draining. Under the pot culture condition, for the Sacramento clay a sufficient aerobic condition was presumably developed when the soil was drained for 14 days, and the N uptake of this treatment was substantially reduced. However, the same practice did not reduce the N uptake in the Amazon varzea soil. Again this can be explained by the slow nitrification in the soil.

The finding that the puddled especially puddled-mixed practice reduced the N uptake in the Sacramento clay as compared with that for the dry-banded practice was also due to the quick nitrification in the soil. When the N was mixed into the soil under puddled condition, it could diffuse to the oxidized soil layer and rhizosphere more quickly than the condition in which the N was banded in the deep soil, resulting in a significant reduction of the N uptake. The finding that a significant reduction in the N uptake by this practice in the Sacramento clay but no in Amazon varzea soil suggested that the loss was mainly through nitrification-denitrication, though the loss though volatilization of ammonium-N cannot be excluded. A recent report (Smith and DeLaune, 1984) indicated that the nitrification-denitrification occurs in the rice rhizosphere evidenced by NO_2+N_2 measurement in laboratory. The N loss due to the rhizosphere effect was found to as much as 13% of the total N (Reddy and Patrick, 1986). The refore, any practices which may increase the chance of the applied N to reach the rhizosphere can increase the N to the lost through nitrification-denitrifiction and also absorbed by the roots. If the soils have very low nitrification such as the Amazon varzea soil, the N uptake is supposed be increased.

In California and many other major rice growing areas, to increase the efficiency of the ammonium N fertilizer for rice, the practices which may reduce the loss due to nitrification-denitrification such as deep and band placement (Broadbent and Mikkeslen, 1968; Cao et al., 1984 a; Cao et al., 1984 b; and Mitsui, 1956), continuous flooding (Mitsui, 1956 and Ponnamperma, 1972), use of nitrification inhibitors (De Datta, 1981; Prasad and De Datta, 1979; and Wells, 1977) and use of slowly releasing fertilizer (De Datta, 1981; and Prasad and De Datta, 1979) have recommended. This, however, may not be particularly needed in the Amazon varzea soils having very low nitrification, In fact, in the rice culture (direct seed and mechanized production) developed in the Amazon regions-Surinam, Guyana and Jari Rice Project in Brazil (where the author had worked for more than 13 years between 1972 and 1986), a subsurface basal dress of the N is not practiced. If the finding of this report is found to be generally true in all the Amazon varzea soils, such practice is well justified.

Recovery of Soil N and Fertilizer N by Rice Under Different Conditions

Table 3 gives the recoveries of soil N and fertilizer N (tagged) by the rice in the two soils under different pot sizes. It is seen that the recovery of soil N as well as the tagged fertilizer N in the Sacramento clay varied greatly with the different conditions while this was not the case in the Amazon soil. In the Sacramento clay the recoveries of both soil N and the tagged N reduced significantly when the pot size was reduced to .25kg soil per pot. When the pot size 2 kg soil per pot the recoveries of the tagged N and the soil N were 53 and 4.73%, respectively, and these dropped to 29.9 and 2.49%, respectively, when the pot size was reduced to .25kg per pot. The balance sheet analysis of the tagged N indicated that the N not accounted for (lost through denitrification presumabley) under the bigger pot size was 5.5%, but this increased dramatically to 29.5% under the smaller sizepot. In the Amazon varzea soil the change in pot size hardly affected the recoveries of both the soil N and the tagged N. The tagged N lost in the smaller size pot (.25kg per pot) was 4%, and though the tagged N lost in

Table 3. Recoveries of soil N and tagged fertilizer N by Earlirose rice in two soils as affected by size of soil volume in pot in Amazon varzea soil and Sacramento clay

Experiment sources	Amazon varzea soil		Sacramento clay	
	Expt. #2	Expt. #3	Expt. #2	Expt. #1
Pot size kg/pot	25	3	.25	2
F. N applied mg/kg	200	200	200	200
F. N uptake mg/kg	126	132	60	106
%	63	66	29.9	53
F. N lost %	4	ND	29.5	5
Total soil N mg/kg	2,660	2,660	1,320	1,320
Soil N uptake mg/kg	117	112	32.8	62.5
%	4.4	4.2	2.49	4.73

F. N Tagged fertilizer N.

the bigger pot (3 kg per pot) was not determined, the nearly same tagged N recoveries found in the two pot sizes suggested the N lost in the bigger pot would not be different greatly from 4%.

Again the difference in the nitrification in the two soils may explain the marked difference found for the recoveries between the two soils. The mineralized soil N and the tagged N in the soils could reach the oxidized layer more quickly under the smaller size pot than under the bigger size pot. Therefore, more N would be lost through nitrification-denitrification in the smaller size pot for the Sacramento clay having quick nitrification. While for the Amazon soil the pot sizes would hardly affect the N recoveries because of low nitrification.

Balance Sheet of Fertilizer N as Influenced by Different Management Practices

Table 4 gives the balance sheet for the recoveries of the tagged N in the soil-plant system in the Sacramento clay as affected by different practices of land preparations (dryland and puddled), N applications (banded and mixed) and water managements (0 DD and 14 DD) in pot experiment #1 in which the pot size was 2 kg soil per pot. It is seen from Table 4 that the rice shoots, roots, soil organic matter and clay minerals, respectivey, recovered 25 to 53, 7.5 to 16, 22 to 27 and 1.5 to 5% of the tagged N depending on different practices. The total recoveries were 63 to 95% while the tagged N not unaccounted for (lost) were 5.5 to 37% depending on the practices. Under the condition of dryland-banded, the tagged N lost was 5.5% and this increased sharply to 25% under the condition of puddled-mixed. Draining for 14 days increased the tagged N loss by approximately 14% over that of continuous flooding (0 DD). The puddled-mixed practice slightly increased the fixation of the tagged N by clay minerals and the immobilization by soil organic matter.

The puddled-mixed practice apparently increased the chance of applied N to diffuse

Table 4. Balance sheet of tagged N in Sacramento clay by different soil-water-fertilization management practices (pot culture experiment #1, 2 kg air dry soil per pot, and 400 mg N per pot added)

Treatment	Tagged		fertilize N		recovery	
	Shoot %	Root Soil %	Orgagic %	Clay-fixed %	Total %	Lost %
Dry-banded-0 DD	53.0	16.0	23.5	2.0	94.5(±6.4)	5.5
Dry-banded-14 DD	43.5	15.0	22.0	1.5	82.0(±6.4)	18
Pudd.-mixed-0 DD	37.5	10.5	27.0	5.0	75.0(±9.9)	25
Pudd.-mixed-14 DD	24.5	7.5	26.0	5.0	63.0(±6.4)	37

Lost Those not accounted for are supposed to be lost.
Figures in the parenthes are the standard errors.

to the rhizosphere as well as the oxidized soil layer where nitrification-denitrification could could take place resulting in 20% more loss of the fertilizer N. Puddled-mixed could also increase the chance of the fertilizer N to be intercepted by the aerobic soil microorganisms in the rhizosphere and oxidized soil layer resulting in 4% higher N immobilization than dryland-banded. The puddled-mixed was also supposed to increase the contact of applied N with clay minerals resulting in 3% higher fixation. Therefore, substantially lower recovery of the fertilizer N by the rice under puddled-mixed condition than under dryland-banded was due mainly to the greater loss through denitrification and partly to the increased fixation by the clay minerals and immobilization by the soil organisms. Fixation of N by clay minerals may retard the absorption by rice. However, recent literature suggests that the clay-fixed N is readily released and absorbed by rice (Keerthinsingle at al., 1984 and Keerthinsingle at al., 1985). Therefore, in the long run N-fixation by clay minerals is beneficial for the N conservation.

Table 5 gives the balance sheet of for the recoveries of the tagged N in the soil-plant system in the two soils as affected by different land preparations and placements in pot experiment #2 in which smaller size of pot (.25kg per pot) was used. It is seen that in the Sacramento clay the total recovery of the tagged N was 57 to 69% and this in the Amazon soil ranged from 95 to 97%. The N recovered by the rice shoot in the Sacramento clay was 25 to 36% and this in the Amazon soil was 60 to 66%.

In pot experiment #1 the fertilizer N was banded at a depth of 5cm while this, in pot experiment #2, was a depth of 3 cm. This, in the Sacramento clay, apparently enabled the banded N to diffuse the oxidized soil layer more quickly in the #2 experiment resulting in a substantially greater loss of the N. It was found that puddled and mixed increased the N loss, respectively, by 2—5 and 10% indicating the mixed was significantly more effective in reducing fertilizer N recovery than the puddled.

Under the condition more conducive to nitrification and denitrification in pot experiment #2, 35 to 43% of the fertilizer N was lost from the soil-plant system in Sacramento clay. And this in the Amazon varzea soil was substantially lower only 3 to 7% For this, the recovery of fertilizer N by the rice (shoots and roots) in the Amazon

Table 5. Balance sheet of tagged N in two soils as affected by different soil-water-fertilization management practices (pot culture experiment #2, .25 kg air dry soil per pot, and 50 mg N per pot added)

Treatment	Shoot %	Root %	Soil organic %	Clay-fixed %	Total %	Lost %
			Sacramento clay			
Dryland	32.1	9.0	20.3	3.5	64.9(±11.7)	35.1
Puddled	26.7	8.8	20.8	3.5	59.8(±9.1)	40.2
Banded	35.1	11.3	20.5	2.0	68.9(±10.7)	31.1
Mixed	24.7	6.5	20.5	5.0	56.7(±11.7)	43.3
			Amazon varzea soil			
Dryland	62.8	12.5	21.8	trace	97.1(±0.7)	2.9
Puddled	63.3	11.5	18.5	trace	93.3(±10.0)	6.7
Banded	59.4	13.0	21.5	trace	93.9(±9.2)	6.1
Mixed	64.6	11.8	20.5	trace	96.9(±3.9)	3.1

Lost, Those not accounted for are supposed to be lost.
Figures in the parenthes are the standard errors.

varzea soil (73 to 76%) was approximately twice of that in Sacramento clay (31 to 47%).

The soil organisms in the Amazon varzea soil immobilized nearly the same amount of fertilizer N as those in Sacramento clay. The clay minerals in Sacramento clay fixed 2 to 5% of fertilizer N depending on the treatments, while the clay minerals in the Amazon varzea soils showed little N fixation. In the Amazon soil where virtually neither nitrification nor fixation of N by clay minerals took place, puddled-mixed increased the recovery of fertilizer N presumably because the puddle and mixed increased the diffusion of N in the soil so that interception by root surface was increased.

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利用N^{15}標識酸硫銨探討不同土壤—水分—肥料管理方式對水稻氮吸收的影響

王 接 皇

摘 要

本研究使用N^{15}標識硫酸銨，以盆栽試驗探討巴西亞馬遜河下游沼澤土和美國沙加緬度粘土，在不同土壤—水分—肥料管理下，所施氮肥被水稻吸收利用情形。

試驗結果顯示，亞馬遜沼澤土與沙加緬度粘土水稻在開花期之氮肥回收率分別爲60～67%及25～59%；後者依不同的土壤管辦而有很大差異。會導致土壤好氣狀態之發展或導致所施氮肥往氧化層擴散之各種土壤管理均沙使加緬度粘土之肥料回收率降低，而亞馬遜沼澤土則無此現象；前者土壤中所施銨態氮肥在好氣狀態下迅速硝酸化，而後者則否。所施肥料氮素被土壤微生物固定之量在兩種土壤差異不大（19～21%），只是沙加緬度粘土之粘土礦物略有固氮能力（２～５%）而已。故兩種土壤隨者土壤管理差異所致氮肥收率之差異主要係因沙加緬度土壤之硝化作用較盛，易導致脫氮損失所致。

爲防止水田硝化作用，吾人常利用氮肥深肥，持續淹水，施用緩效性氮肥或硝化抑制度等處理，但在本試驗之亞馬遜沼澤土，因硝化作用進行極爲緩慢，故上述各處理似非必要。